الـجـمـهـوريـة الـجـزائريـة الديمـقـراطية الشـعـبيـة
PEOPLE'S DEMOCRATIC REPUBLIC OF ALGERIA

وزارة الـتـعلـيم الـعـالي و البحث العلمي
جامـعـــة محمد بوضياف بالمسيلـة
كـلـيـة التكنولوجيا
قسم الهندسة الكهربائية

MINISTRY OF HIGHER EDUCATION AND SCIENTIFIC RESEARCH
MOHAMED BOUDIAF UNIVERSITY OF M'SILA
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DEPARTMENT OF ELECTRICAL ENGINEERING

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المسيلة في : 15 ديسمبر 2024

شهادة إدارية

بخصوص مطبوعة الدروس الخاصة بالأستاذ

زريق عصام

بناءً على محضر اللجنة العلمية لقسم الهندسة الكهربائية تحت رقم: 365/ق.هـ.ك/2024 المنعقد بتاريخ 06 نوفمبر 2024 والمتضمن تعين الخبراء: الأستاذ واقني فيصل أستاذ محاضر "أ" بجامعة المسيلة الأستاذ بوزيدي رياض أستاذ محاضر "أ" بجامعة المسيلة، والأستاذ سعودي كمال أستاذ بجامعة البويرة وذلك لتقييم مطبوعة الدروس الخاصة بالأستاذ زريق عصام أستاذ محاضرة "ب" بقسم الهندسة الكهربائية لجامعة المسيلة تحت عنوان: " Energie et environnement "

مطبوعة دروس تم تحريرها باللغة الإنجليزية تحت عنوان: " energy and environment "

وبعد إطلاع رئيس اللجنة العلمية ورئيس القسم على التقارير الواردة و التي كانت كلها ايجابية، وعليه فإن اللجنة لا ترى مانعا أن تتخذه سندا في تدريس طلبة السنة الثانية ليسانس ألية، كهروتقني و كهروميكانيك ، شعبة ألية، كهروتقني وكهروميكانيك على التوالي ،ميدان علوم و تكنولوجيا و أن تعتمد في أي تقييم للمسار العلمي للأستاذ المعني.

رئيس اللجنة العلمية

بوقرة عبد الرحمان

رئيس القسم

دفداف المبروك

ملاحظة: سلمت هذه الشهادة للمعني(ة) لاستعمالها في حدود ما يسمح به القانون.

Democratic and Popular Republic of Algeria

جامعة محمد بوضياف بالمسيلة

Mohamed Boudiaf University - M'sila

كليـــــــة التكنـــــــولوجيـــــــا

Faculty of Technology

Course Handout

ENERGY AND ENVIRONMENT

Presented by **:**

Dr :ZORIG Assam

This course is intended for students of the second year LMD Sciences and Technology course specializing in Electrical Engineering, Electromechanics & Automation

Teaching objectives

To make the student aware of the different existing energies, their sources and the impact of their uses on the environment.

Content of the subject:

Chapter 1: The different energy resources

Chapter 2: Energy storage

Chapter 3: Consumption, reserves and developments of energy resources

Chapter 4: The different types of pollution

Chapter 5: Detection and treatment of pollutants and waste

Chapter 6: Influence of pollution on health and the environment.

Summary

Chapter I

The different energy resources

I.1. Definition of energy

Energy is an essential basis for social and economic development.

The word "energy", widely used, comes from the Greek word "energia" which means "force in action".

It exists in several forms such as mechanical energy, chemical energy, electrical energy, radiant energy, wind energy, nuclear energy, etc.

Generally speaking, a system has energy if it is capable of producing a transformation of its energy "example: the chemical energy of our cells is transformed in our muscles into mechanical energy which produces a movement" or of exchanging energy "example: heat transmitted by a radiator".

The measurement of energy is thus done through its effects and variations.

The unit used by physicists to measure energy is the joule (J). Economists rather use the ton of oil equivalent (toe), nutritionists the calorie (cal).

In electricity we use the watt-hour (Wh) or the kilowatt-hour (kWh).

Note: Energy is not created or lost: it is transformed. This is the principle of energy conservation. When a system has no exchange with the external environment, its energy is assumed to remain constant and it is said to be isolated.

I.2. Forms of energy

Energy exists in various forms, all related and each form can be converted or changed into another form.

a) Mechanical energy

Mechanical energy is due to movements "kinetic energy; for example, the energy of a car that comes from the combustion of fuel in the engine" or due to position "potential energy; for example, the potential energy of water in a dam".

b) Chemical energy

The creation or breaking of chemical bonds results in the release of energy, usually in the form of heat. For example, chemical energy derived from the respiration process that powers the human body or energy derived from gasoline.

c) Nuclear energy

Nuclear energy is energy released by nuclear reactions involving the nuclei of certain atoms of "radioactive material", either by fission or fusion of the nuclei.

For example, the energy of the sun is produced from a nuclear fusion reaction in which hydrogen nuclei fuse to form helium nuclei.

d) Thermal energy

Thermal energy is due to the movements of atoms or molecules of a body, it is obtained from several sources: sun, combustion of wood and fossils "coal, oil, gas" or electricity "Joule effect".

e) Radiative energy “radiant or luminous”

Radiative energy is very common in our daily lives; the sun lights us, a radiator heats us or a microwave oven heats our food.

The sun is a major source of radiation received on Earth. Radiative energy is the only energy t

I.3. Energy sources

Energy sources are either raw materials "oil, gas, coal, ..." or natural phenomena used to produce energy "sun, wind, ...", these sources can be classified into non-renewable and renewable energy. hat can propagate in a vacuum, in the absence of matter.

I.3.1. Non-renewable energies

A non-renewable energy resource is a resource that is destroyed during its use and/or that is renewed more slowly than the speed with which it is used. There are two families of non-renewable energy; Fossil energy and fissile energy.

I.3.1.1. Fossil fuels

The term "fossil fuel" refers to energy produced from raw materials found underground such as oil, coal, natural gas. These raw materials come from the decomposition of organic matter "plants and living organisms".

Fossil fuels now account for more than three-quarters of global energy consumption "transport, industries, heating, etc."

I.3.1.1.1 Coal

Coal is a generic term for sedimentary rocks of biochemical origin that are rich in carbon.

These rocks are fossil fuels that were formed in the Carboniferous period,

by the slow transformation of sedimented dead organisms, under the action of pressure and temperature over geological time.

I.3.1.1.2. Fuels from petroleum

Crude oil is a dark and viscous mineral oil that comes from the subsoil, and which comes from the remains of dead animals and plants, petroleum is therefore a non-renewable fossil energy source.

Refining makes it possible to isolate its various constituents and to obtain, after purification, fuels. The combustion of this fuel creates energy.

I.3.1.1.3. Natural gas

Millions of years ago, microscopic living organisms were buried in the ground and transformed into natural gas under the action of high temperature, high pressure and the absence of contact with air. Gas is a very good fuel that is used for cooking, heating water in homes, producing heat, etc. It is found in pockets at depths between 3000 and 4000 meters below the surface of the Earth.

I.3.1.2. Fissile energies

Nuclear energy is the binding energy between the constituents of the atomic nucleus. This nucleus is an assembly of protons, with a positive charge, and neutrons without a charge that are very strongly bound despite the electrical repulsion between protons.

In heavy atoms; the nucleus contains many protons that repel each other.

Some of these nuclei "for example uranium or thorium" can become unstable and break up, releasing part of their binding energy. This is the fission of the atom.

In very light atoms; two nuclei can fuse to form a heavier but more stable atom, releasing considerable energy. This is the fusion, for example of hydrogen nuclei into helium nuclei.

I.3.2. Renewable energies

A renewable energy resource is a resource that is not destroyed during its use and/or that has the capacity to renew itself naturally, at least at the same speed as it is used. These resources depend on elements that nature constantly renews: wind, sun, wood, water, the heat of the Earth, etc.

I.3.2.1. Wind energy

The word "wind" comes from the Greek Aeolus, the god of winds. The term also means "fast", "lively" or "inconstant".

Wind energy is an indirect form of solar energy. The absorption of solar radiation in the atmosphere creates differences in temperature and pressure that set the air masses in motion, creating wind.

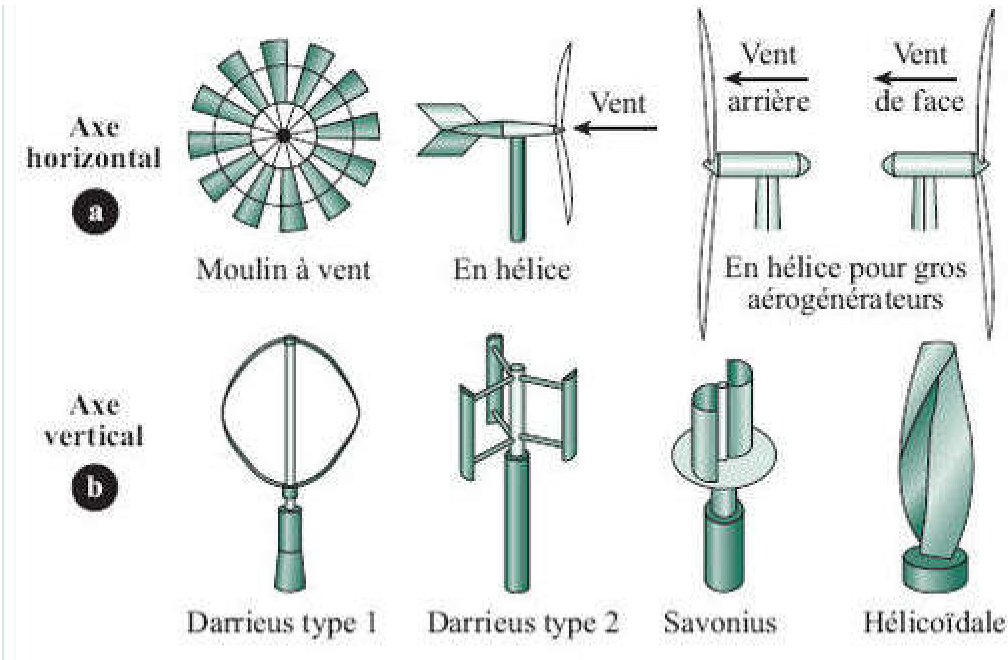
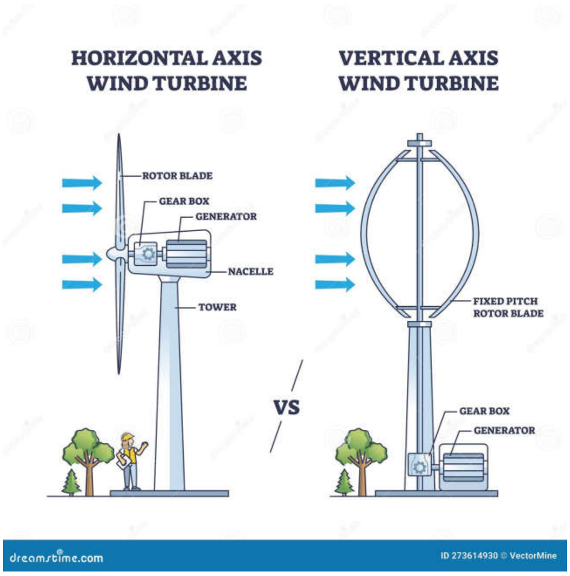


Fig.I.1 type of wind turbine



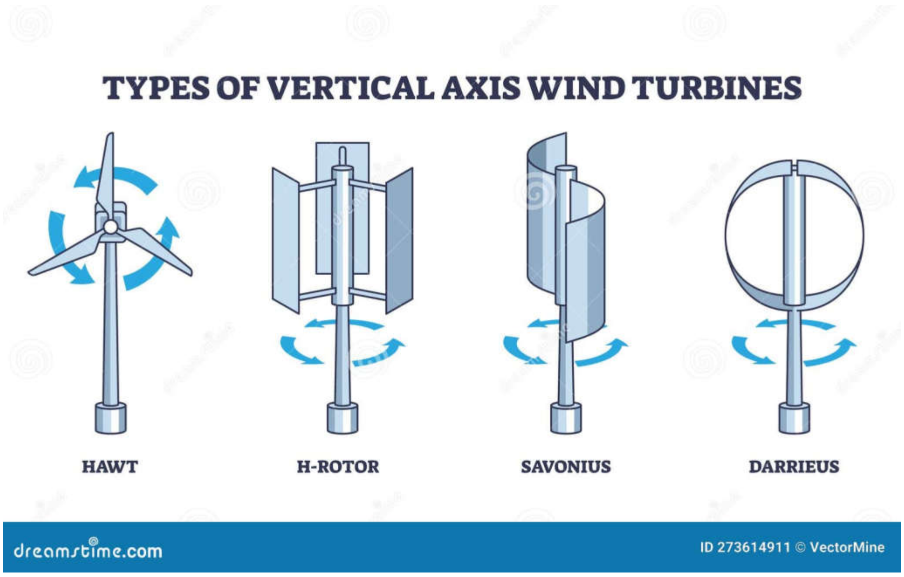


Fig.I.2 example of of wind turbine

I.3.2.2. Solar energy

Solar energy, produced by the sun's radiation on the Earth, represents an inexhaustible and 100% green natural source. It is used directly in three ways; thermodynamics, thermal and photovoltaics, which are the subject of new developments to improve their performance and economic competitiveness.

Research in this context, for several years, has been oriented to extend applications and reduce costs.

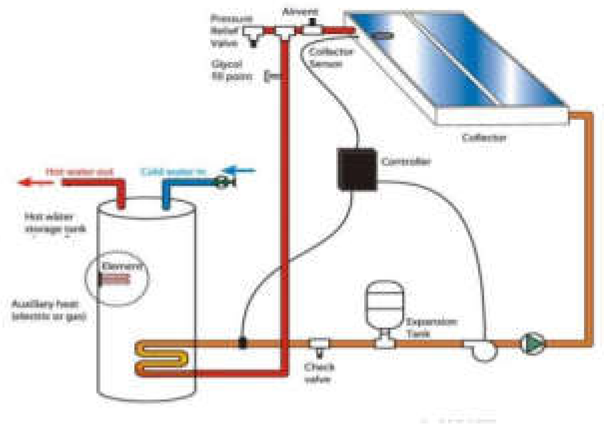


Fig.I.3 solar hot water system configuration.

I.3.2.2.1. Solar thermal energy

Solar thermal energy takes advantage of the sun's radiation, through solar thermal collectors, in order to convert it into heat. This heat is mainly used for heating domestic hot water and heating premises. The installation of solar thermal panels makes it possible to meet part of the domestic hot water and heating needs, and also allows significant savings to be made, with relatively low maintenance and operating costs.

This technique is inexhaustible, non-polluting, clean and does not release greenhouse gases. However, the investment cost of a solar thermal installation is relatively high.

I.3.2.2.2. Thermodynamic solar electricity

Thermodynamic solar energy is one of the direct use modes of solar energy.

This technique involves transforming the energy of solar radiation into heat, through collectors "parabolic or parabolic cylinder collectors", whose role is to concentrate solar radiation on a single focus, to heat a fluid "oil or molten salts from 250 to 1000°C" and produce electricity by means of a thermodynamic cycle. This fluid vaporizes water, which drives a turbo-alternator, as in conventional thermal power stations.

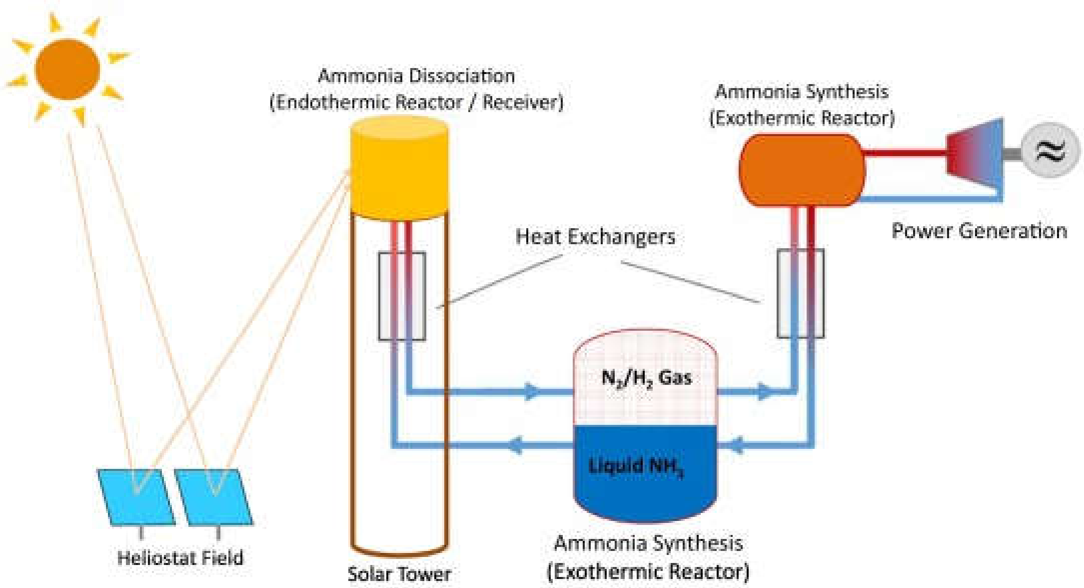


Fig.I.4 solar hot water system configuration.

I.3.2.2.3. Photovoltaic energy

Photovoltaic energy is based on the photoelectric effect "discovered in 1839 by Edmond Becquerel", to create a direct electric current from radiation. The first photovoltaic cell appeared in 1954. To do this, it uses photovoltaic panels, composed of solar cells that transform light energy into electrical energy. Photovoltaic conversion is based on the absorption of photons in a semiconductor material that provides electrical charges, therefore current, in an external circuit.

Fig.I.5 Photovoltaic energy.

I.3.2.3. Hydroelectric energy

Hydraulic energy, the world's leading renewable energy, represents nearly 90% of the world's renewable electricity production.

Hydraulic energy produces electricity using the driving force of watercourses.

Water at altitude has gravitational potential energy; this energy is captured and transformed in hydroelectric dams. When the water is stored, simply open the valves to start the electricity production cycle. The water rushes into a pipe and heads towards the hydroelectric power station located below.

Fig.I.6. Hydraulic power station

I.3.2.4. Biomass

Biomass is the 2nd renewable energy in the world. It is solar energy stored in organic form through photosynthesis.

It can produce electricity and heat through the combustion of waste and residues of plant or animal organic matter. The term biomass covers a very broad range of materials: wood, waste from wood processing industries, agricultural waste, fermentable fraction of household waste and agri-food industries, landfill biogas or methanization products "slurry, sewage sludge, landfills, etc.".

Includes three main families:

a) Wood energy "solid biomass":

this technique is used in power plants, whose operating principle is the same as that used in conventional thermal power plants operating with coal, oil or gas... except that the fuel used as a heat source is solid biomass. But it can also be used by the boiler of an individual house.

Fig.I.6 solid biomass

b) Biogas "wet biomass": these are the gases that are released from organic matter when it decomposes (through fermentation). Wet biomass plants are factories "large installations called digesters", equipped with large tanks that do not let air in, to promote fermentation. These biogases are used for heating and to produce electricity.

Fig.I.7 Biogas installations

c) Biofuels: a biofuel is a plant fuel or agrofuel assimilated to a renewable energy source, with combustion producing only CO_2 and water vapor and little or no nitrogen oxides and sulfur "NOx, SOx", it is created from the transformation of non-fossil organic materials such as plant materials produced by agriculture "beet, wheat, corn, rapeseed, sunflower, potato, ... etc.".

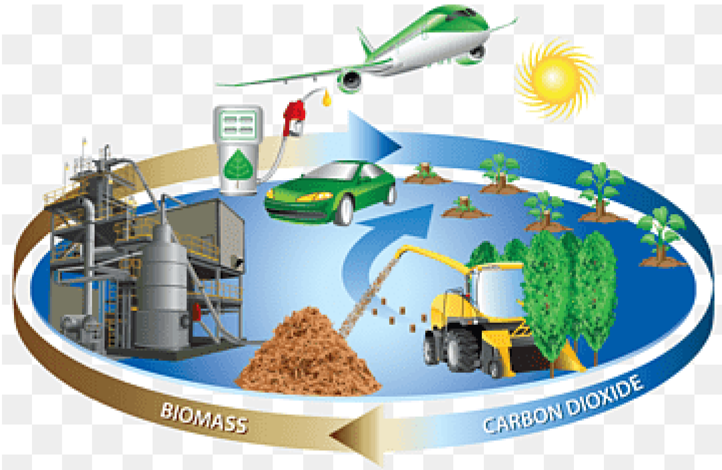


Fig.I.8 Biofuels energy source

I.3.2.5. Geothermal or aerothermal energy

Geothermal energy uses the highest temperature of the Earth's subsoil to produce heat or electricity. Low-temperature geothermal energy is used for heating buildings. High-temperature geothermal energy can produce electricity.

Chapter II

Energy storage

II.1. Definition and general information on energy storage

Energy storage depends on the type of energy;

- Fossil fuels "coal, gas and oil" are stored naturally in reservoirs, once extracted, they can easily be transformed or transported from a technical point of view.
- Storage for intermittent energies mainly concerns the storage of electricity and heat. It is more complex, because of the dependence of their production on energy vectors such as electricity, heat or hydrogen.

Note: The main purpose of energy storage is to balance demand and electricity production "it allows adaptation over time between supply and demand for energy",

One of the major drawbacks of renewable energies in general is its intermittency due to the intermittent nature of wind, sun or geothermal energy. This is why storage systems will play an important role in the development of these energies in the future.

Storage is differentiated according to its capacity "quantity of available electrical charge":

− storage is said to be low capacity when it is of the order of kWh,

− high capacity if it is greater than 10 MWh. In this case, we speak of massive energy storage.

II.2. Electricity storage

II.2.1. Direct electricity storage

Direct storage of electricity is achieved by using large capacitors "electrical components consisting of two conductive plates storing opposite electrical charges", whose capacity is measured on the microfarad scale, which have limited storage capacities and whose costs are more or less high.

Another avenue for direct electricity storage is storage by supercapacitors "capacitors made from superconducting materials". However, these "superconductors" require operating temperatures close to absolute zero "- 273°C" which are technically as difficult as they are expensive to maintain.

However, SUPERCAPACITORS intervene more in terms of power than energy "capable of delivering high power for a very short time". They can therefore represent an interesting complement to batteries. The battery/Supercapacitor combination can prove particularly effective in the case of hybrid vehicles.

II.2.2. Indirect storage of electricity

Except in capacitors or Supercapacitors, electricity cannot be stored directly. It is therefore necessary to convert electricity into another energy that can be controlled. The different storage methods are classified according to the primary conversion energies.

II.2.2.1. Mechanical storage mode

A- Pumped storage energy transfer stations "PEST":

This storage system is based on the principle of gravity energy "hydraulic energy therefore at dams". This is the most widely used solution for storing energy from power plants and it allows large quantities of electrical energy to be stored, it uses two basins at different altitudes. The surplus electricity from the network is used to pump water from the lower basin into the upper basin. In the event of a deficit in electricity production, the water pumped into the upper basin turns a turbine by gravity and restores the accumulated energy.

Fig II.2. The pumping energy transfer station (PETS), a proven solution for mass storage.

B- Compressed Air Energy Storage CAES

Compressed air energy storage stations are designed, quite simply, to store compressed air “in the form of pressure in underground cavities instead of pumping water”, using a compressor, during off-peak hours. This air is released to turn turbines that produce electricity, to deliver it during peak hours.

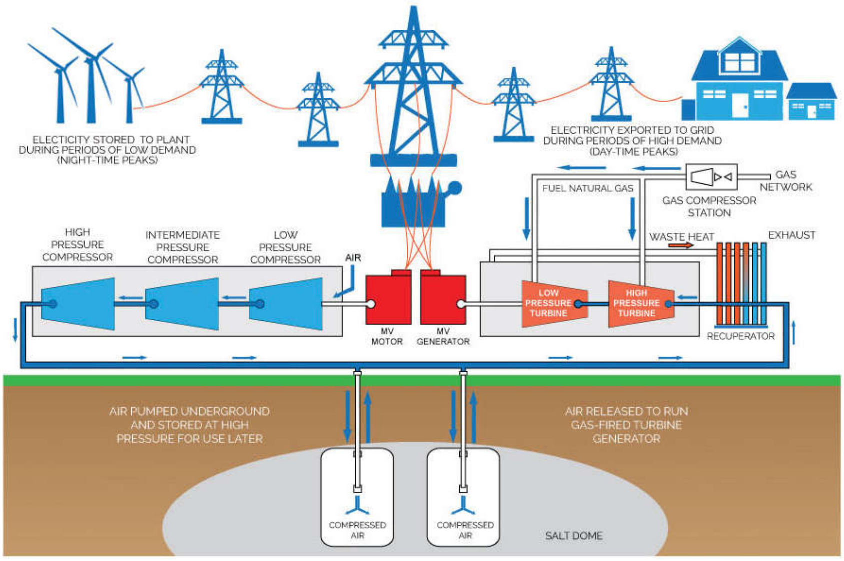


Fig II.2. Compressed Air Energy Storage CAES

C- Flywheels

Flywheels have long been used to regulate steam engines. Today, their principle allows energy to be stored in the form of mechanical rotation. Electricity rotates a mass at very high speed around a cylindrical axis in an insulated box, which converts electrical energy "in the case of surplus production" into kinetic energy. This conserved kinetic energy can then be recovered in the form of electricity using an alternator "dynamo principle"

Fig II.3. Flywheels

Fig II.4. A project in China, claimed as the largest flywheel energy storage system in the world, has been connected to the grid.

II.2.2.2. Chemical storage mode

The principle of this electricity storage mode is based on the conversion of chemical energy into electrical energy, mainly concerns batteries and the hydrogen vector.

A- Batteries

Electricity storage is achieved through electrochemical reactions that involve circulating ions and electrons between two electrodes. The chemical components can be different from one technology to another, thus creating a wide variety of batteries.

- **Flow batteries**

These batteries are rechargeable batteries, allow the storage of electrochemical couples "electrolytes" outside the reaction cell, in reservoirs separated by a membrane, in the liquid state. The electrolytes circulate through an ion exchange cell.

Flow batteries represent the advantages of being able to quickly recharge "the system replaces the electrolytes with reservoirs". They can support more than 10,000 charge cycles, plus the self-discharge effect is almost zero

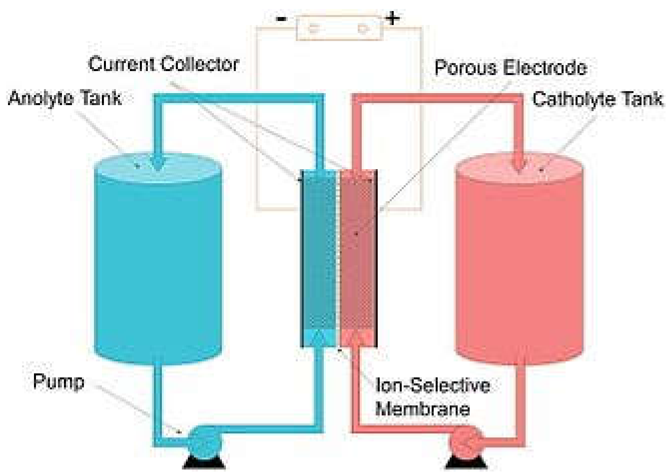


Fig.II.5. A typical flow battery consists of two tanks of liquids which are pumped past a membrane held between two electrodes

- **Advanced" lithium-ion batteries**

The operation of the lithium-ion battery is based on the reversible exchange of the lithium ion between a positive electrode and a negative electrode. Thus, we can cite as an example, the most important system, to date, which is in Zhangbei "China" in 2011, with a capacity of 20 to 36 MW over 4 to 6 hours with a wind production of 100 MW and a solar production of 40 MW.

Fig.II.6. Batteries lithium-ion

- **Zn-Br batteries**

A zinc-bromine battery is a rechargeable battery system that uses the reaction between zinc metal and bromine to produce electric current, with an electrolyte composed of an aqueous solution of zinc bromide. Zinc has long been used as the negative electrode of primary cells. It is a widely available, relatively inexpensive metal. It is rather stable in contact with neutral and alkaline aqueous solutions. For this reason, it is used today in zinc–carbon and alkaline primaries.

The leading potential application is stationary energy storage, either for the grid, or for domestic or stand-alone power systems. The aqueous electrolyte makes the system less prone to overheating and fire compared with lithium-ion battery systems.

These batteries are based on the zinc/bromine couple "Zn+/Br-". Several demonstrators have been produced, for example a 400 kWh system produced in Akron "Michigan" USA, some commercial installations are now operational.

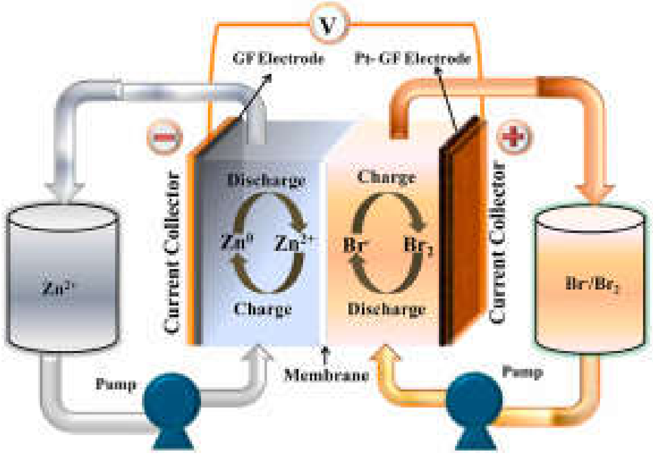


Fig.II.7 Zn-Br batteries

Zinc–bromine batteries share six advantages over lithium-ion storage systems:

100% depth of discharge capability on a daily basis.

Little capacity degradation, enabling 5000+ cycles

Low fire risk, since the electrolytes are non-flammable

No need for cooling systems

Low-cost and readily available battery materials

Easy end-of-life recycling using existing processes

They share four disadvantages:

Lower energy density

Lower round-trip efficiency (partially offset by the energy needed to run cooling systems).

The need to be fully discharged every few days to prevent zinc dendrites, which can puncture the separator.

Lower charge and discharge rates

These features make zinc-bromine batteries unsuitable for many mobile applications (that typically require high charge/discharge rates and low weight), but suitable for stationary energy storage applications such as daily cycling to support solar power generation, off-grid systems, and load shifting.

B-Hydrogen vector

Hydrogen does not represent a direct energy source like wind energy for example, but an energy vector. It is not found in pure form in nature, but must be extracted from water "H2O" by electrolysis. Hydrogen gas can be directly used "as fuel" or stored and converted back into electricity "by a fuel cell". The principle of the fuel cell is to convert chemical energy into electrical energy from hydrogen that will be used as fuel. The overall efficiency is less than 50% and their lifespan is insufficient in the context of applications coupled to the electricity grid.

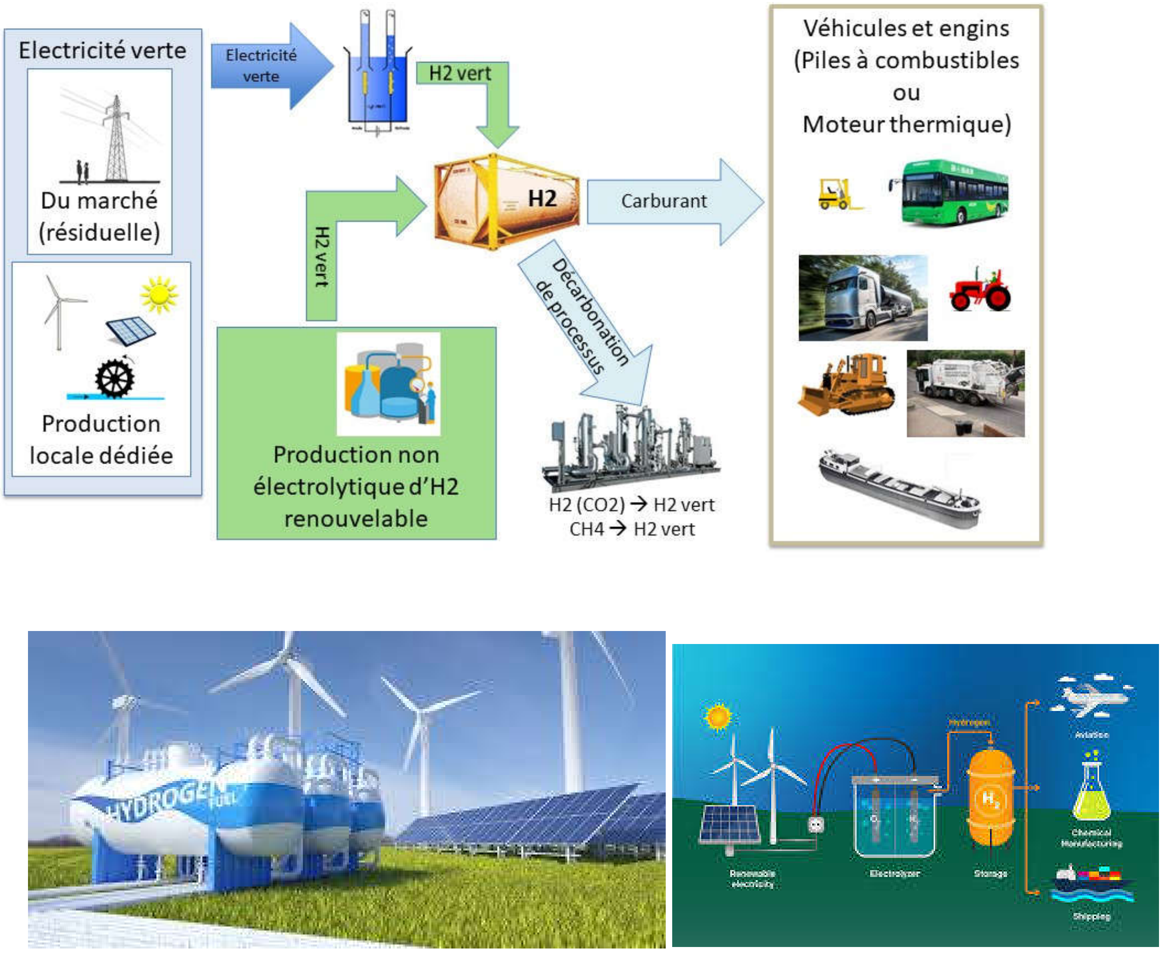


Fig.II.8. Green hydrogen

I.2.2.3. Thermal storage of "heat"

The development of thermal storage is directly linked to the development of thermodynamic solar farms. Storing this thermodynamic solar heat would reduce the effects of its intermittency and the gap between the most productive periods "day/summer" compared to the periods of greatest demand "evening/winter". This storage mainly concerns the heating "or air conditioning" of buildings. Any material has the capacity to release or store heat via thermal transfer. This transfer can be:

A-Storage by sensible heat

Raising the temperature of a material allows energy to be stored in the form of heat. This is the case, for example, of a stone placed near a fireplace, once it has stored the heat, it can be moved and release its heat. This principle is the same for solar water heaters: they recover the heat during the day to then restore it, with an average efficiency of around 40% for the most recent systems. The preferred materials are water, synthetic oil, rock or concrete.

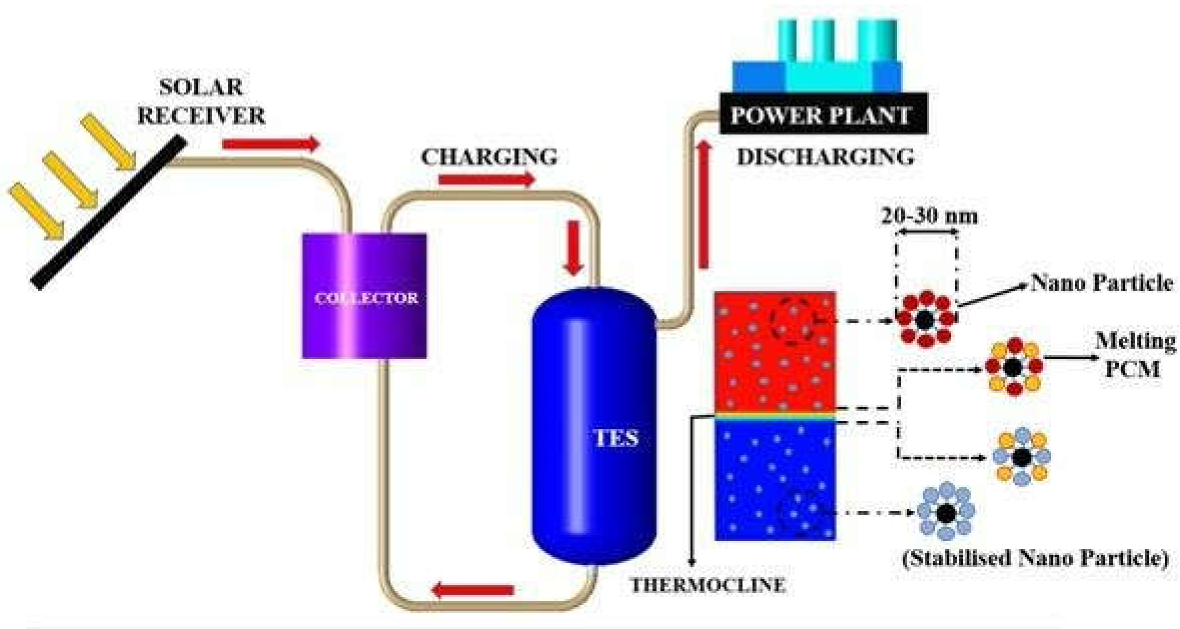


Fig.II.9. Sensible heat thermal storage system.

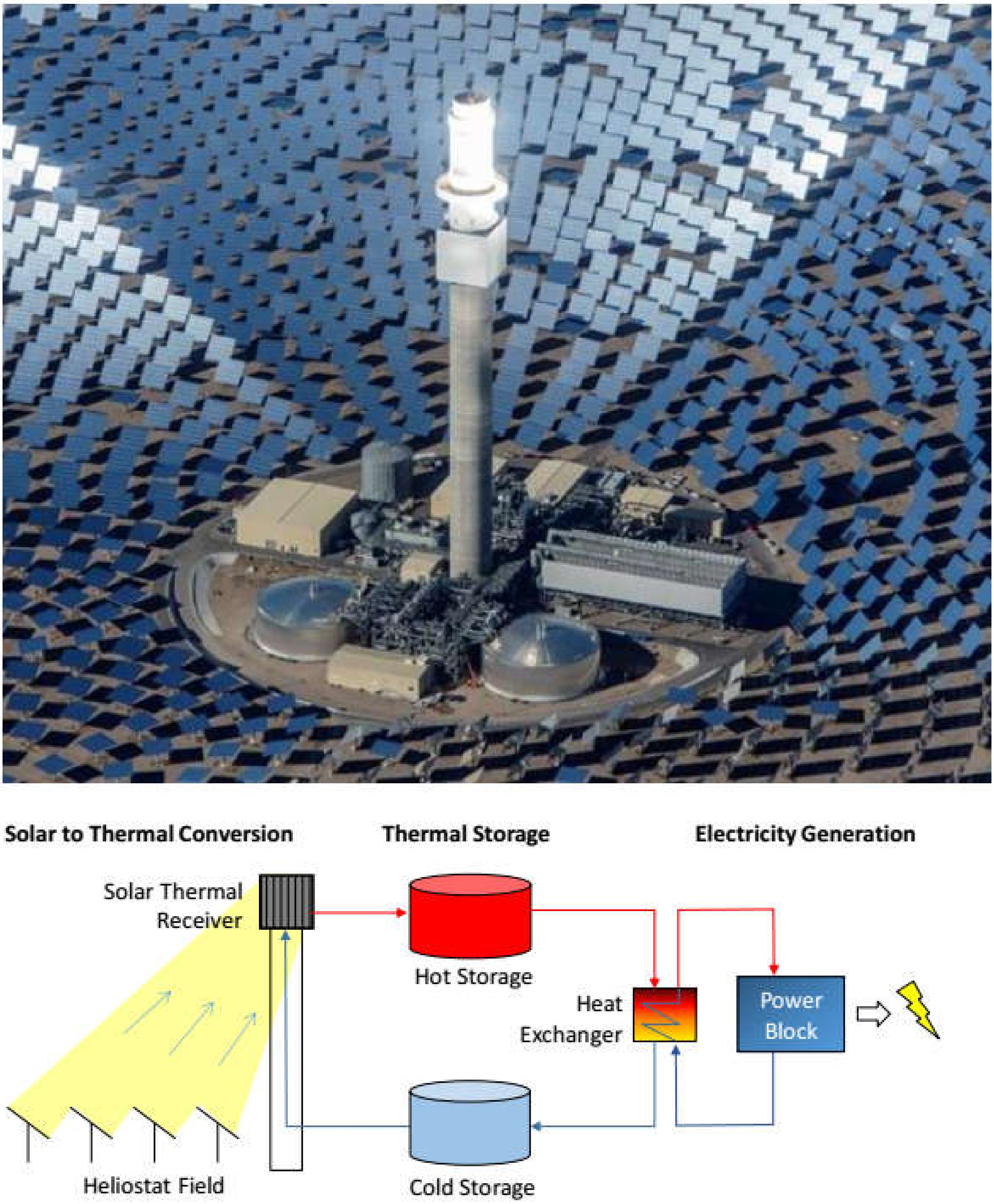


Fig.II.10. Top: 110 MW Crescent Dunes CSP plant with 1.1 GWh of thermal storage using molten nitrate salt [15]. Bottom: Schematic of sensible two-tank thermal storage system in a CSP plant

B-Latent heat storage

This storage method is based on phase change materials "PCMs", these materials store energy when they change their state "for example solid-liquid". The reverse transformation allows the accumulated energy to be released in the form of heat or cold, with an efficiency of around 60%. Several types of these materials "organic fatty acids and paraffins or inorganic hydrated salts" serve as a thermal regulator depending on the heat provided by the sun, to temper buildings. There are currently no large-capacity storage facilities based on this principle but many projects are underway.

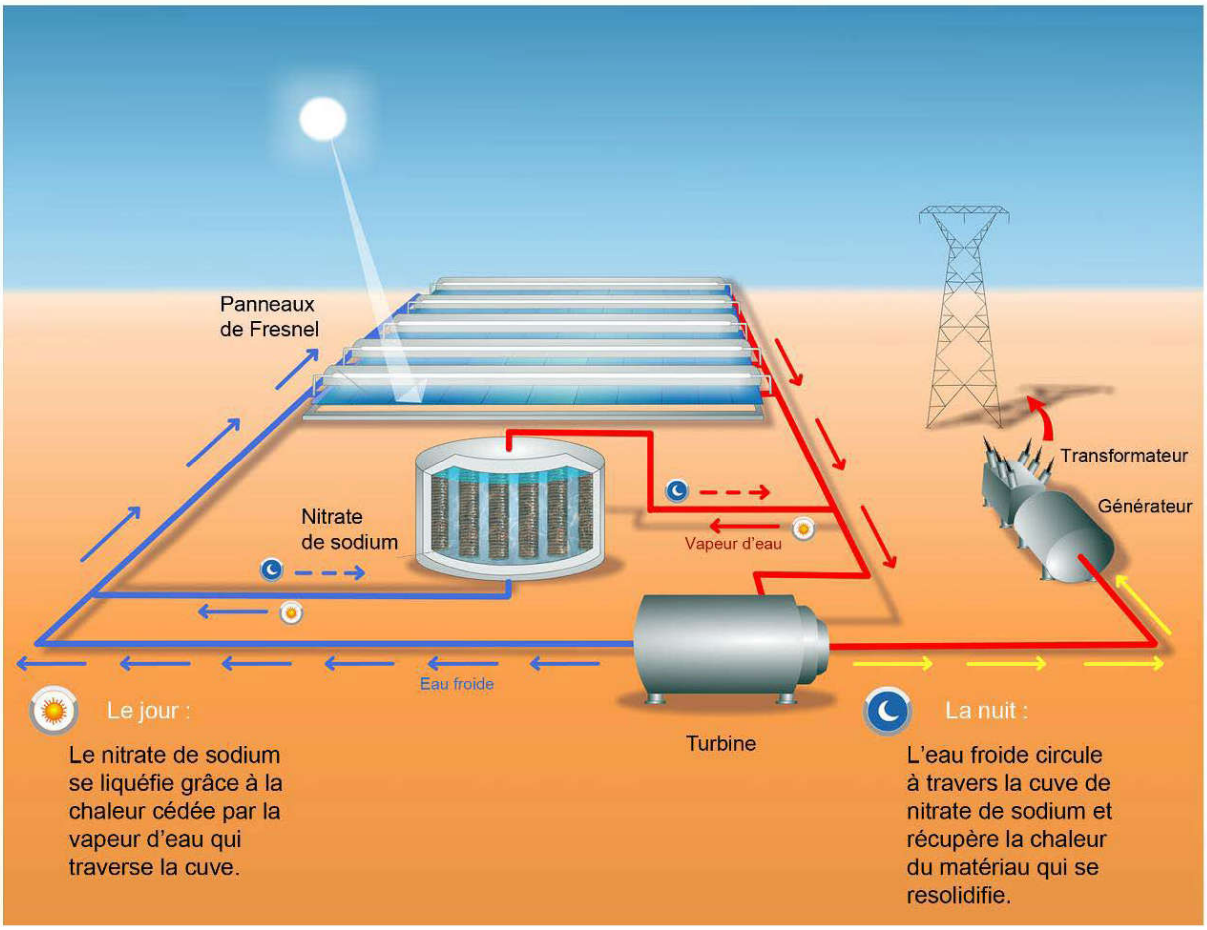


Fig.II.10. Latent heat storage

Chapitre III

Consommations, reserves and developments of energy resources

III.1. World energy consumption

World energy supply and consumption refers to the global supply of energy resources and its consumption. The system of global energy supply consists of the energy development, refinement, and trade of energy. Energy supplies may exist in various forms such as *raw resources* or *more processed and refined* forms of energy. The raw energy resources include for example coal**, unprocessed oil & gas, uranium**. In comparison, the refined forms of energy include for example refined oil that becomes fuel and electricity. Energy resources may be used in various different ways, depending on the specific resource (e.g. coal), and intended end use (industrial, residential, etc.). Energy production and consumption play a significant role in the global economy. It is needed in industry and global transportation. The total energy supply chain, from production to final consumption, involves many activities that cause a loss of useful energy.

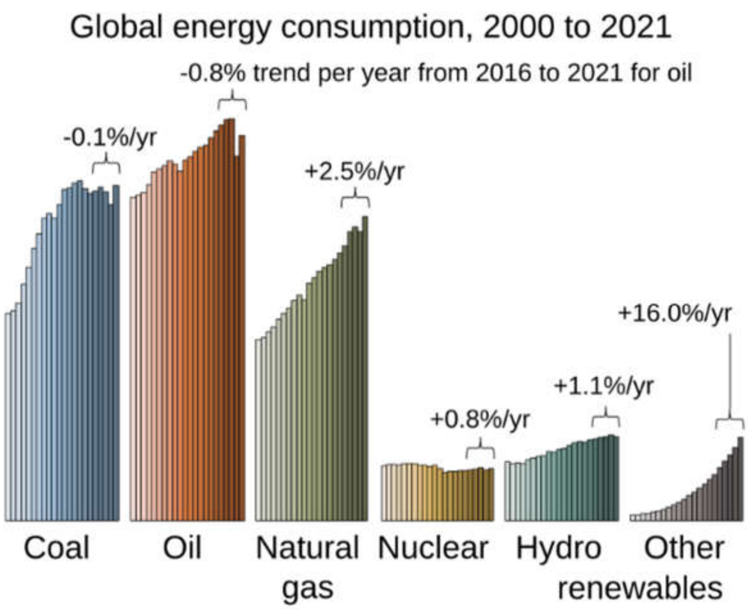


Fig. III.1 Global energy consumption, measured in exajoules per year: **Coal, oil, and natural gas** remain the primary global energy sources even as renewables have begun rapidly increasing.

As of 2022, energy consumption is still **about 80% from fossil fuels**. The Gulf States and Russia are major energy exporters. Their customers include for example the European Union and China, who are not producing enough energy in their own countries to satisfy their energy demand. Total energy consumption tends to increase by about 1–2% per year. More recently, renewable energy has been growing rapidly, averaging about 20% increase per year in the 2010s.

Two key problems with energy production and consumption are greenhouse gas emissions and environmental pollution. Of about 50 billion tonnes worldwide annual total greenhouse gas emissions, 36 billion tonnes of carbon dioxide was a result of energy use (almost all from fossil fuels) in 2021. Many scenarios have been envisioned to reduce greenhouse gas emissions, usually by the name of net zero emissions.

There is a clear connection between energy consumption per capita, and (**Gross Domestic Product**) GDP per capita.

A significant lack of energy supplies is called an energy crisis.

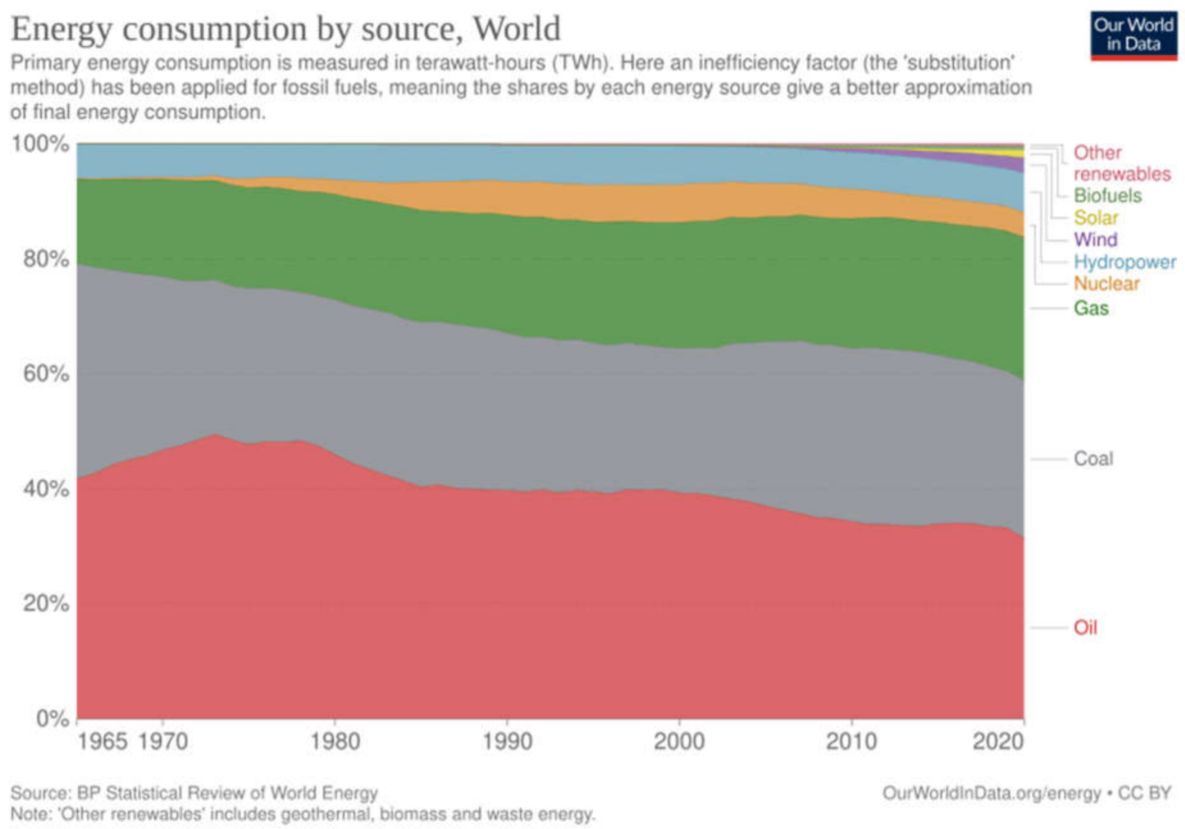


Fig. III.2. Primary energy consumption by source (worldwide) from 1965 to 2020

III.2 Primary energy production

Primary Energy refers to first form of energy encountered, as raw resources collected directly from energy production, before any conversion or transformation of the energy occurs.

Energy production is usually classified as:

Fossil, using coal, crude oil, and natural gas;

Nuclear, using uranium;

Renewable, using **biomass, geothermal, hydropower, solar, wind**, **tidal, wave, among** others.

Primary energy assessment by IEA (International *Energy Agency*) follows certain rules to ease measurement of different kinds of energy. These rules are controversial. Water and air flow energy that drives hydro and wind turbines, and sunlight that powers solar panels, are not taken as PE, which is set at the electric energy produced. But fossil and nuclear energy are set at the reaction heat, which is about three times the electric energy. This measurement difference can lead to underestimating the economic contribution of renewable energy.

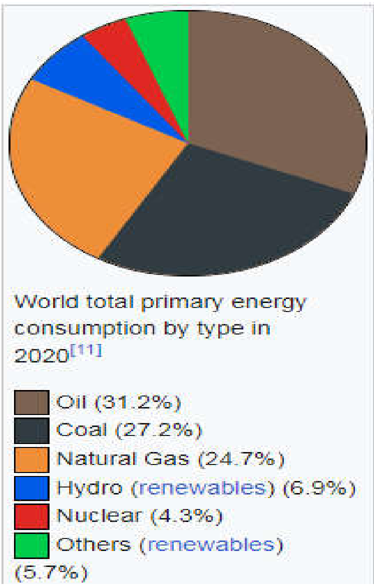


Fig. III.3 Word total primary energy consumption by type in 2020.

Enerdata (***Enerdata is an independent research company that specialises in the analysis and forecasting of energy and climate issues.)*** displays data for "Total energy / production: Coal, Oil, Gas, Biomass, Heat and Electricity" and for "Renewables / % in electricity production: Renewables, non-renewables".

The table lists worldwide PE and the countries producing most (76%) of that in 2021, using Enerdata. The amounts are rounded and given in million tonnes of oil equivalent per year (1 Mtoe = 11.63 TWh (41.9 petajoules), where 1 TWh = 109 kWh) and % of Total. Renewable is Biomass plus Heat plus renewable percentage of Electricity production (hydro, wind, solar). Nuclear is nonrenewable percentage of Electricity production. The above-mentioned underestimation of hydro, wind and solar energy, compared to nuclear and fossil energy, applies also to Enerdata.

The 2021 world total energy production of 14,800 MToe corresponds to a little over 172 PWh / year, or about 19.6 TW of power generation.

Fig. III.4. World map with primary energy use per person in 2021

Largest Primary Energy producers (76% of world production) as of 2021, given in million tonnes of oil equivalent per year

	Total (MToe)	Coal	Oil & Gas	Renewable	Nuclear
China	2,950	71%	13%	10%	6%
United States	2,210	13%	69%	8%	10%
Russia	1,516	16%	78%	2%	4%
Saudi Arabia	610	0	100%	0	0
Iran	354	0	99%	0	1%
United Arab Emirates	218	0	99%	0	1%
India	615	50%	11%	33%	6%
Canada	536	5%	81%	10%	4%
Indonesia	451	69%	17%	14%	0
Australia	423	64%	33%	3%	0
Brazil	325	1%	55%	42%	2%
Nigeria	249	0	47%	53%	0
Algeria	150	0	100%	0	0
South Africa	151	91%	1%	8%	0
Norway	214	0	93%	7%	0
France	128	0	1%	34%	65%
Germany	102	27%	3%	47%	23%
World	**14800**	**27%**	**53%**	**13%**	**7%**

III.3. Evolution of global energy demand

The factors that weigh on the evolution of energy demand in the world are:

- The increase in the world population "9 to 10 billion inhabitants by 2050",
- the efforts of **developing countries** to fill their economic gap "growth of 8 to 10% in China and India",
- The maintenance of a slight growth in energy demand in **developed countries**, the demand for primary energy continues to grow but its geographical distribution is changing.

CHAPTER IV

DIFFERENT TYPES OF POLLUTION

IV.1. Definition

The term pollution comes from the Latin "**pollutio**" which means dirt or stain. This term could be a phenomenon or element that disrupts an established balance.

Therefore, pollution is the introduction into the air, water or soil of a foreign substance "not naturally present in the environment" or the variation of its rate of existence. This leads to environmental degradation or disruption of the ecosystem and can lead to the migration or extinction of certain species unable to adapt to change.

Industrial, urban or agricultural human activity produces polluting substances that are the origin of organic, chemical or radioactive pollution. These polluting substances are emitted into the atmosphere "air pollution", discharged into the water "water pollution" or spread on the soil "soil pollution". They may exist in the form of gas, dissolved substances or particles.

IV.2. Types of pollution

We can specify essentially 4 types of pollution:

1- **Organic pollution:**

Organic pollution results from the daily activities of human beings "excrement and corpses", industrial activities related to agri-food production or agricultural activities such as animal or plant production.

Fig.IV.1 Organic pollution

2- **Chemical pollution:**

Chemical pollution is mainly found in water and air, it is produced by insecticides or pesticides used to eliminate insects and protect plants, chemical fertilizers.

Fig. IV.2 Chemical pollution

3- Radioactive pollution:

Radioactive pollution is due to nuclear waste, directly or indirectly from human activity, which introduces radioactive substances into the environment.

Fig.IV.3 Radioactive pollution

4-Solid waste pollution:

Solid waste pollution seriously denatures the waters and soils of the planet, pollutes our beaches, pollutes the streets of our cities and the meadows of our countryside, tons of waste dumped in nature bottles, tissues, plastic materials, polymers, there are everywhere and are proof of a serious failure on the part of many individuals to respect the elements.

Fig.IV. 4 Solid waste pollution

IV.3. Sorts of pollution

Pollution exists in the three states of matter, so we can distinguish three types of pollution:

IV.3.1. Air pollution

Air is composed of 78% nitrogen, 21% oxygen and 1% other gases. The change in this composition, due to human emissions, implies a deterioration in air quality.

There are too many polluting gases:

Carbon Monoxide CO: Carbon monoxide is formed during incomplete combustion, approximately 55% from motor vehicles and 26% from heating and industrial combustion plants. It inhibits the transport of oxygen in the blood.

Sulfur Dioxide SO2: Sulfur dioxide SO2 is a colorless gas with a pungent odor that irritates the eyes and respiratory tract, 91% of this gas is produced by the combustion of fossil fuels used for domestic heating and industrial boilers and the remaining percentage is produced by means of transport and the smelting of iron ores containing sulfur.

Nitrogen dioxides NO2: Nitrogen dioxide NO2 is a toxic, suffocating gas with a pungent odor, it is formed from nitric oxide NO, 56% of this gas is produced by internal combustion engines and 30% by combustion plants.

Volatile organic compounds VOC: Volatile organic compounds VOC include several compounds, they come from the incomplete combustion of fuels and fuels of transport vehicles, industry, crafts and households and by evaporation of solvents. They can be biogenic "natural origin" or anthropogenic "human origin". The best known VOC compounds are butane, propane, ethanol, acetone, solvents in paints, solvents in inks, etc.

Lead Pb: Lead enters the environment mainly through car exhaust fumes. Large particles fall to the ground, small particles enter the air and remain in the atmosphere. Leaded gasoline is not the only contributor that increases the concentration of lead in the environment, other activities such as the combustion of fossil fuels, industrial processes and the burning of solid waste also increase this concentration.

Ammonia NH3: Ammonia NH3 is a mainly agricultural pollutant, emitted during the storage and spreading of manure and slurry from animal breeding, but also during the manufacture of ammonia fertilizers. It is a hazardous waste for the environment and health, it can cause burns and lung irritation.

Trace Metal Elements "TME": TME or heavy metals correspond to a physical definition. They are naturally present in soils, some of which are essential to plants, the TMEs best known for their danger are cadmium, mercury, chromium, zinc and scrap metal containing TME. The latter are contained in the air we breathe, from which they are emitted through the chimneys of household waste incineration plants and steel mills. Some of them are very toxic.

Tobacco: Tobacco smoke is the primary source of pollution in the home, it is the main nuisance in the premises. More than 3,000 substances have been identified in tobacco smoke "nicotine, tar, carbon monoxide, ... and", these harmful substances are responsible for several diseases; cancer, addiction, asthma, respiratory diseases, ... and.

Greenhouse gases: The presence of gases in small quantities in the atmosphere "natural greenhouse effect", such as water vapor or carbon dioxide "CO_2" increases the average temperature of our planet, which makes it habitable. In addition to water vapor and carbon dioxide, the main natural greenhouse gases are methane "CH_4", nitrous oxide "N_2O" and ozone "O_3".

IV.3.2. Water pollution

The earth is also called the blue planet, because it is covered by about 71% of water on the surface "ocean, seas, rivers... etc.", water also exists in the aquifers of the soil "groundwater" and also exists in the air in the form of "vapor".

Water pollution is any "chemical, physical or biological" alteration of its quality and nature, which has a harmful effect and makes its use dangerous and "or" disrupts the aquatic ecosystem.

There are two types of sources of water pollution, localized sources and non-localized sources. If the pollutants are discharged in a specific place, it is a localized source of pollution "for example: sewers, factories, mines, oil tankers and agriculture", otherwise, if we cannot locate a specific place where the pollutants are discharged, it is a non-localized source of pollution "for example: acid deposits in the air, traffic, pollutants from groundwater or spread by rivers",

IV.3.2.1. Different categories of pollution

The different categories of pollution are:

- Disease pollutants: This category includes pollutants that cause diseases such as bacteria, viruses and parasitic worms that thrive in untreated wastewater.

Note: 80% of diseases in developing countries are due to water.

- Waste pollutants: These wastes need oxygen to decompose, this can lower the oxygen level of the water, which affects other species living in the water.
- Water-soluble inorganic pollutants: This category is that of water-soluble inorganic pollutants such as acids, salts and toxic metals, they make water unfit for consumption and cause the death of aquatic life.
- Nutrient pollutants "water-soluble nitrates and phosphates": These pollutants cause excessive growth of algae and aquatic plants, which also decreases the amount of oxygen in the water.
- Organic compound pollutants: This category includes organic compound pollutants such as oil, plastics and pesticides, they are harmful to humans as well as to all plants and animals living in the water.
- Suspended sediment pollutants: These pollutants reduce the absorption of light by water and they diffuse dangerous compounds such as pesticides into the water.

- Radioactive compound pollutants: These pollutants are the most dangerous, they can cause cancer, malformations in newborns and even genetic modifications.

IV.3.3. Soil pollution

Soil fulfills a multiplicity of complex functions, its pollution directly or indirectly influences water and air, because it represents an interface between land, air and water. This pollution is mainly due to; deposits of polluting substances, the use of pesticides and chemical fertilizers, the spreading of chemicals.

Chapter V

Detection and treatment of pollutants and waste

V.1. Introduction

Controlling the source of pollution must be the first management option considered because, not only does it contribute to the overall approach to reducing emissions of substances responsible for chronic exposure of populations, but it also contributes to the overall approach to improving the quality of environments. Furthermore, without controlling the sources, it is not economically or technically relevant to try to control the impacts. If it is impossible to completely remove the source of pollution, it will nevertheless be necessary to ensure that the impacts from residual sources are controlled and acceptable for populations and the environment.

V.2. Pollutant detection

V.2.1. In water and soil

For the detection of toxic substances in water, companies are developing alert tools based on measuring the stress of phosphorescent bacteria. The decrease or loss of fluorescence indicates the presence of a toxic substance. It is measured automatically every minute for a quarter of an hour: the slope of the curve delivered indicates the concentration of the toxic substance. For the measurement of soil pollution, companies are launching four detectors: for explosives, hydrocarbons, PCB-type transformer insulators and aromatic polycycles. The kits allow the tests to be carried out in less than half an hour.

V.2.2. Remote sensing of atmospheric gases

There are laboratories that have a remote sensing system for atmospheric gases by infrared emission of the scanner type. This remote detection device, the

SIGIS 2 (Scanning Infrared Gas Imaging System - Bruker, Ettlingen-Germany) operates in passive mode. It does not require an artificial infrared source since it uses, as a source, the natural emission of gaseous bodies.

The SIGIS 2 allows remote detection (up to a few kilometers), identification and quantification of any gas plume present in the atmosphere.

Currently, most gas detectors used are fixed specific sensors, which only allow one-off measurements (at a single point) and can only detect a single gas (single-gas detectors).

The advantage of SIGIS2 is that it is a mobile system that can spatially and simultaneously detect several gases present in a plume (multi-gas detector). Thanks to an infrared camera, SIGIS 2 can also be used for night-time measurements.

The combined use of 2 or even 3 SIGIS 2s opens the way to the 3-dimensional reconstruction of a gas plume. This device can be intended for any type of company or urban site that needs to control gas emissions, whether for environmental monitoring purposes or for site security purposes.

Fig V.1. Bruker SIGIS 2 atmospheric gas detection device.

2.3. Particulate concentration measurement system for industrial chimneys

The increasingly strict limitation of admissible levels for industrial discharges increasingly leads to questioning the metrological means used until now on industrial chimneys.

It is in this context that a new means of measurement has been developed that can be used by industry in order to make the monitoring of emissions into the atmosphere more effective and thus better control industrial processes. The challenge is to offer manufacturers a system capable of measuring both abnormally high levels and very low levels, sometimes of the order of a hundred µg/m3, thus offering the possibility of anticipating any drift by intervening very early on. This high sensitivity also makes it possible to optimize maintenance periods and therefore the associated costs.

Types of companies concerned:

- Household waste incinerators
- Special waste incinerators
- Cement plants
- Paper mills
- Glassworks
- Production plants

3. Classification of the different decontamination techniques

The different decontamination techniques can be classified according to:

- the nature of the processes used,
- the treatment location,
- the fate of the pollutants.

It should be noted that the rehabilitation of a site will often implement different techniques.

3.1. Classification according to the nature of the processes used

The different decontamination techniques can be classified according to the nature of the processes used, namely:

- Physical processes: the principle consists of using fluids (water or gas), present in the soil or injected, as a vector to transport the pollution to extraction points or to immobilize it.

- Biological processes: they consist of using micro-organisms, most often bacteria (but also fungi and plants), to promote the total or partial degradation of pollutants. Some bioprocesses also make it possible to fix or solubilize certain pollutants.

- Thermal processes: they use heat to destroy the pollutant (e.g. incineration), isolate it (e.g. thermal desorption, thermolysis, etc.), or make it inert (e.g. vitrification, etc.).

- Chemical processes: they use the chemical properties of pollutants to, using appropriate reactions, render them inert, destroy them or separate them from the polluted environment.

3.2. Classification according to the treatment location

Decontamination techniques can also be classified according to the treatment location. The following treatments are distinguished:

- Off-site treatments (or ex situ): they involve the excavation/extraction of the polluted environment (waste, soil, water) and its evacuation to a suitable treatment center (incinerator, technical landfill, etc.).
- On-site treatments (or on site): they consist of excavating the polluted soil or water and treating it on the site itself.

- In-situ treatments (or in place): they correspond to a treatment without excavation: the soil and groundwater are left in place. This involves either extracting the pollutant alone, or degrading it or fixing it in the soil.
- Containment: this consists of preventing/limiting the migration of pollutants.

3.3. Classification according to the fate of pollutants

Remediation techniques can be classified according to the fate of pollutants. There are two possibilities:

- Immobilization: it involves techniques that modify the mobility and/or toxicity of pollutants by two types of processes:

-Modification of the pollutant (change in behavior, toxicity) by acting on the level of redox, complexation, precipitation.

- Modification of the receiving environment: reduction of permeability and porosity: by solidification or stabilization or by confinement,

- Destruction (total or partial) by the chemical, thermal, physical and biological processes previously mentioned.

Chapter VI

Impact of pollution on health and the environment

1. Introduction

Many human activities (industrial, chemical, agricultural, and even domestic) are responsible for environmental degradation:

- Global warming.
- Climate change and ecosystem disruption.
- Depletion of the ozone layer.
- Pollution of soil and water, but also of the air.

These environmental threats constitute a major risk to human health (appearance and/or resurgence of various pathologies: cancerous diseases, infectious diseases, congenital malformations, cardiovascular and respiratory pathologies, reduction in quality of life and well-being, etc.).

2. Effects of pollution

The effects of pollution depend on the personal sensitivity of the exposed individual: age, state of health, smoking, predispositions.

According to experts, they also depend on the following factors:

- Individual exposure to different sources of pollution.

- Duration of exposure to these levels.

- Respiratory flow at the time of exposure.

- Interaction with other compounds present in the atmosphere such as pollen, fungal spores, etc.

It is therefore difficult to predict the effect of a given level of pollution on the health of a given person. However, there are people who are a priori more sensitive than others to the effects of air pollution. For example, children, the elderly, people with respiratory or cardiovascular diseases, and pregnant women generally constitute so-called sensitive populations.

In terms of air pollution, there is no threshold below which pollutants have no effect on health. Some people are affected by very low levels.

There is a short-term statistical link between daily pollution levels, commonly observed in large cities, and certain public health indicators (hospitalizations, work stoppages, anticipated mortality, etc.).

Faced with these health issues, public authorities define pollution levels beyond which temporary or permanent actions to reduce emissions are implemented. These are alert thresholds and limit values.

3. Impact on health

3.1. Depletion of biodiversity

This transformation of the environment generally results in a depletion of biodiversity (Biodiversity, in the etymological sense of the term, refers to the diversity of living things, i.e. all the processes, lifestyles or functions that lead to maintaining an organism in a state of life. This term is much too broad to have a real scientific connotation) then by the disruption of the functioning of ecosystems (characterizing an environment in which the physicochemical conditions are relatively homogeneous and allow the development of a set of living organisms. In an environment, climatic conditions (such as temperature, solar radiation, humidity), geological conditions, etc.). The weakening and disappearance of the ecological services provided by these ecosystems (purification mechanisms, soil stabilization, etc.) generate a generalized degradation of the living environment for both organisms and for humans and their activities.

3.2. Cardiovascular diseases

Hypertension (high blood pressure), hypercholesterolemia and smoking are the main risk factors identified in cardiovascular diseases. Other factors such as obesity, physical inactivity, a diet too rich in fat also interact. However, it seems that environmental factors do not play a major role in the onset of cardiovascular diseases, with the exception of exposure to carbon monoxide which could promote cardiac arrhythmias and the aggravation of angina symptoms. Excessive and prolonged exposure to noise in sensitive people can cause hypertension and cardiac ischemia (WHO-1999).

3.3. Cancers

The appearance of cancerous diseases is particularly accentuated by different factors, namely:

- Lifestyle (alcohol, tobacco, diet).
- Genetic functions
- Hormonal functions.

However, other factors whose role is less preponderant should not be neglected, such as those related to the environment, especially in certain populations and/or certain regions.

Three major sources of contamination should be cited and are detailed below (via food consumption, via air or via radiation):

- Source 1: Food (pesticides, polychlorinated biphenyls, chlorinated derivatives, etc.)
- Source 2: Air (pesticides, polycyclic aromatic hydrocarbons, smoking, benzene, asbestos, etc.)
- Source 3: Radiation (ionizing, non-ionizing, etc.)

3.4. Respiratory diseases

Respiratory diseases are particularly accentuated by different factors and several causes, namely:

- ✓ Suspended particles
- ✓ Nitrogen oxide
- ✓ Sulfur dioxide
- ✓ Tropospheric ozone
- ✓ Pollution inside buildings

3.5. Allergies

- Pollens (see figure 10)
- Molds
- Dust mites (see figure 11)
- Pets, pests and crawling insects

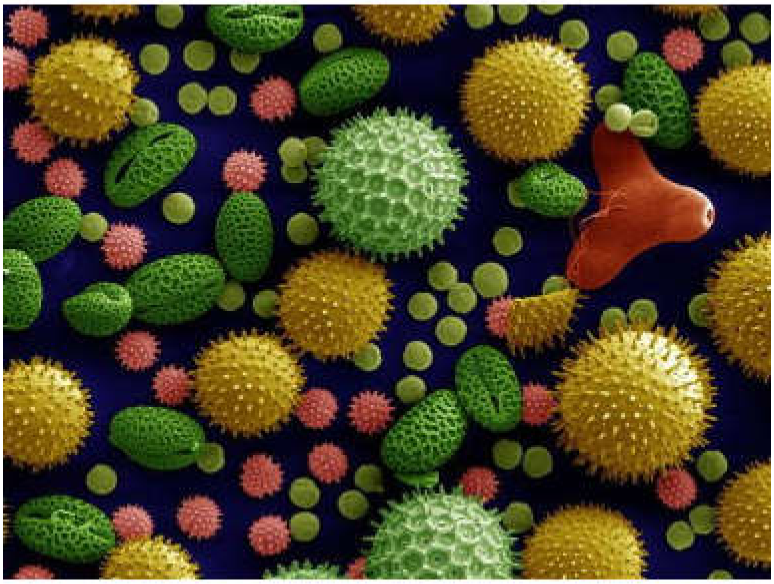


Fig VI.1. Pollen from several plants: sunflower (Helianthus annuus), morning glory (Ipomoea purpurea), Sidalcea malviflora, Lilium auratum, evening primrose (Oenothera fruticosa) and common castor bean (Ricinus communis).

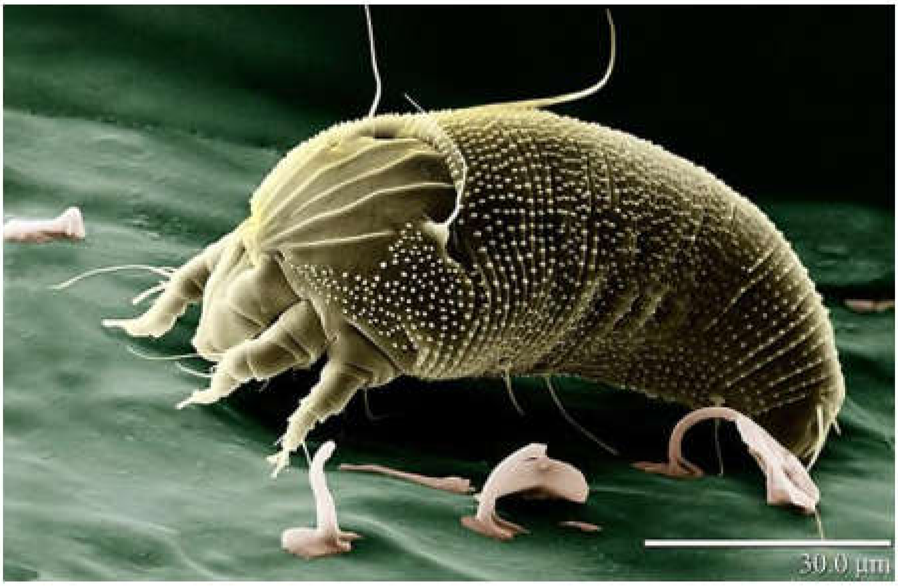


Fig VI.2. Photo of a mite.

4. Quantification

In terms of figures, the number of premature deaths (or excess mortality) are:

- 3.7 million premature deaths in 2012 worldwide due to ambient outdoor air pollution in urban and rural areas (Source: WHO);
- 420,000 premature deaths caused in 2010 by air pollution in the EU (Source: European Commission).
- 21,400 premature deaths in EU-25 in 2000 caused by tropospheric ozone.
- 13,000 premature deaths per year, including 24 children, caused by PM2.5 in Belgium in 2000.
- 350,000 premature deaths (including 680 children) caused by PM2.5 in the EU-25 population. Added to this are hundreds of thousands of cases of bronchitis, thousands of hospitalizations and millions of days of medication (Source: CAFE Programme).
- A long-term increase of 10 µg/m3 in PM2.5 concentrations in ambient air would cause an increase (Source: WHO):

- 6% in mortality risks

- 12% in cardiovascular disease risks

- and 14% in lung cancer risks

- ➢ 7.3% of total mortality would be attributable to chronic exposure to PM10 concentrations above 20 µg/m3 in Liège in 2004 (Source: APHEIS)

5. Impact on the environment

There are many effects of pollution on the environment, we can mention:

- ➢ Oil spill which is dangerous for marine animals.
- ➢ Air pollution which is caused by exhaust pipes and factory fumes.
- ➢ CFCs (chlorofluorocarbons) which make holes in the ozone layer. Whether chemical, physical or biological, pollution causes changes in the environment. Depending on its nature, pollution affects the physiology and behavior of exposed organisms or the characteristics of biotopes (geographically delimited living environment in which the ecological conditions (temperature, humidity, etc.) are homogeneous, well defined, and sufficient for the development of living beings that reside there (called biocenosis), with which they form an ecosystem...) and therefore the composition and structure of populations.
- ➢ Consequences of the hole in the ozone layer Substances that deplete the ozone layer (CFCs, HCFCs, HBFCs, halons, CCl4, CH3CCl, CH3Br, etc.) have indirect repercussions on human health. Indeed, the destruction of this layer induces an increase in harmful UV-B radiation at ground level and its hole could contribute in one way or another to global warming.
- ➢ The increase in UV-B at ground level leads to:

- An increase in skin cancers.

- An increased risk of developing cataracts.

- A possible weakening of the immune system in both light- and dark-skinned individuals, resulting in greater vulnerability to attacks by infectious diseases.

- Alteration of the environment In other words, chemical substances (heavy metals, endocrine disruptors, etc.) and physical effects (heat, light, radioactivity) on the one hand weaken organisms and their ability to reproduce and on the other hand alter environmental conditions (pH, oxygen, ultraviolet, etc.).

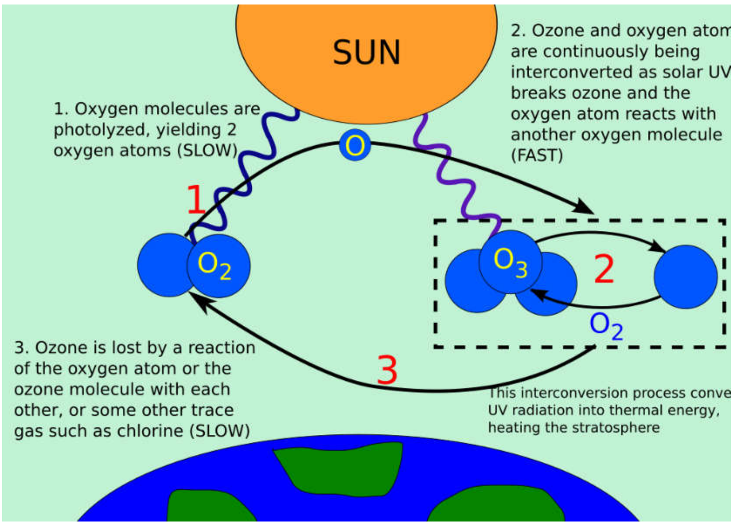


Fig.V.3 The ozone cycle

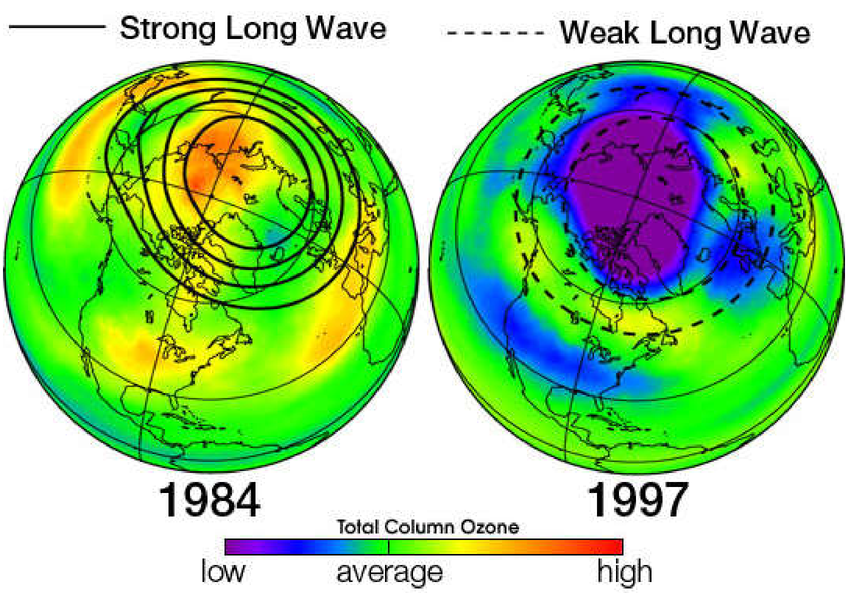


Fig.V.3 Ozone hole in North America during 1984 (abnormally warm, reducing ozone depletion) and 1997 (abnormally cold, resulting in increased seasonal depletion). Source: NASA